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State University of New York, College of Environmental Science and Forestry, Faculty of Environmental and Forest Biology, Syracuse, New York, USA

Nematode populations in Adirondack forest soils and their potential role in sulfur cycling

C. C. Mishra and M. J. Mitchell[1])

With 2 figures

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1. Introduction

Nematodes constitute a major component of the soil fauna in a variety of ecosystems and are major contributors to decomposition processes (Abrams and Mitchell 1980; Freckman & Caswell 1985; Mitchell *et al.* 1978; Sohlenius & Boström 1984; Twinn 1974; Wasilewska *et al.* 1981; Yeates 1981). In addition, nematodes play a critical role in cycling of nutrients including nitrogen and phosphorus (Anderson *et al.* 1983a; Coleman 1986; Coleman *et al.* 1983).

There is only limited information on the role of nematodes in northern deciduous forest ecosystems of North America (Johnson *et al.* 1972, 1973, 1974) although this ecosystem type is a major component of this region (Likens *et al.* 1977). Furthermore, there is no information on the role of nematodes on sulfur cycling in terrestrial ecosystems despite the importance of this element as a nutrient and as a major component of acidic deposition (David *et al.* 1984; Mollitor and Raynal 1983). Recent work has demonstrated that invertebrate macrofauna in aquatic (Lawrence and Mitchell 1985) and terrestrial systems (Morgan & Mitchell 1986) alter the rates of sulfur transfer and transformation.

The objectives of the present study were to present information on (1) the community composition and population density of nematodes within the soils of a northern hardwood and a coniferous forest ecosystem and (2) the potential contribution of nematodes in the hardwood site to sulfur and nitrogen dynamics.

2. Site description

Nematodes were sampled from soils on hardwood and conifer sites located at the Huntington Forest in the Adirondack Mountains of New York. The mean annual temperature is 5.4 °C. Total annual precipitation averages 106 cm with a snowfall of 284 cm. On the hardwood site (elevation 530 m), dominant tree species were *Fagus grandifolia* Ehrh. and *Acer saccharum* Marsh. Major species on the conifer site (elevation 500 m) included *Tsuga canadensis* L. Carr. and *Picea rubens* Sarg. Soils at both sites are from the Becket series (Typic Fragihumod) and are bouldery fine sandy loams. The soil in the conifer site has a thicker layer of organic horizons (O_i and O_e which together equal L, F and H) and more a developed eluviated E horizon than the hardwood site. More detailed site and soil descriptions are given elsewhere (Mollitor & Raynal 1982; Raynal *et al.* 1980).

3. Methods

3.1. Sampling

On 28 September, 11 October, and 22 November, 1985 both the hardwood and conifer sites were sampled by removing 3 soil blocks 50 cm × 50cm × 50 cm. Samples were placed in plastic bags to

[1]) Corresponding author.

avoid desiccation and returned to the laboratory in insulated containers. Within 48 hrs the samples were divided into organic and mineral horizons, and 3 subsamples each of about 250 cm^3 used for extraction. For the November sample the organic horizon was further subdivided into O_i and O_e layers, and mineral horizon into 0—3 cm and 3—6 cm layers which encompass the E and Bsl horizons.

3.2. Extraction, counting and identification

The 250 ml samples were processed by a combination of decanting, sieving and Baermann funnel technique (McBrayer *et al.* 1977; Mishra & Dash 1981). Samples remained in the funnel for 48 h. Nematodes were counted in glass counting dishes under stereo magnification of 100× and classified, based on known feeding habits or morphological characters such as the stomatal structure, into four ecological trophic groups: plant parasites, microbivores (bacterivores), miscellaneous feeders including nonparasitic Dorylaimida of unknown feeding types, and predators (mostly Mononchidae). The plant parasite grouping encompassed plant parasitic and fungal feeders containing all the Tylenchida and known plant parasites of the Dorylaimida (Dash & Pradhan 1984; Mishra & Dash 1981). This group would also include the genus *Aphelenchus* which was not observed in this study. Trophic designation could only be made for late juveniles and adults because only in those stages is there full development of gonads, copulatory organs and stomatal structures (Nicholas 1975). Thus for the September and October samples only late juveniles and adults were counted while for November samples the entire population was enumerated for estimates of density and biomass.

3.3. Population density and biomass estimates

Biomass was calculated using the formula of Andrassy (Freckman 1982) from samples obtained in November using 60 representative nematodes from the organic horizons of the hardwood and conifer sites. A conversion factor for converting to dry mass of 0.25 was used as per Yeates (1979). Nematode population density was expressed on a dry mass basis by drying the soil samples for 48 h at 105 °C. These density estimates were converted to an area basis using information on bulk density and horizon thickness from David (1983).

3.4. Elemental concentration of nematodes

Since we could not obtain sufficient numbers of nematodes from field samples for doing elemental analyses, we utilized *Anguilla sp.* as an analog since it could be easily cultured and harvested in sufficient mass necessary for chemical analysis. Cultures were obtained from Carolina Biological Supply, North Carolina. Subcultures were maintained in 1 l glass containers in apple cider vinegar by adding 50 cm^3 of the original culture to each subculture. Cultures were maintained at 20—25 °C for 4 months. Additional cultural medium was added as needed. After 3 months, sufficient numbers of nematodes were produced for subsampling and analyses. Nematodes were extracted and reextracted in approximately 150 ml of distilled water for 48 h by the method of Peter as described by Southey (1970). The extracted nematodes were placed in a 250 ml flask and allowed to settle for one hour in an incubator after which the supernatant liquid was removed and an additional 150 cm^3 of distilled water added. This washing was repeated 3 times after which the final concentration of nematodes was frozen until further use. Before chemical analyses the nematodes were thawed and 10 cm^3 of concentrate injected through a 13 mm glass fiber filter which resulted in approximately 10,000—15,000 nematodes/filter. The filter with nematodes was washed in distilled water and dried at 65 °C for 24 h. Nematodes were analyzed for total sulfur and HI-reducible sulfur following the methods of Landers *et al.* (1983) on 18 samples. The HI-reducible sulfur fraction would include both inorganic and organic sulfur constituents. The difference between total sulfur and HI-reducible sulfur would constitute the carbon-bonded sulfur constituents. Concentrations of carbon, hydrogen and nitrogen were determined using a Perkin-Elmer Elemental Analyzer (Culmo 1969) on 7 samples.

4. Results

Two plant parasitic taxa, *Hemicycliophora sp.* and *Criconema sp.* were identified at the September sampling only from the hardwood site while only the former taxon was found in the conifer soil. In the conifer site only juveniles of *Hemicycliophora* were observed. The contribution of parasitic and miscellaneous feeding species increased from the organic to the mineral horizons in the hardwood site (Fig. 1). Nematode abundance g^{-1} dry mass decreased with soil depth which corresponded with the change from organic to mineral horizons (Fig. 2). For the organic layers nematode densities were 2.61×10^5 and 0.95×10^5 individuals m^{-2} for the hardwood and conifer site, respectively (Table 1). The mean [± standard deviation (number of samples)] dry mass per individual nematode for the combined sampling of ne-

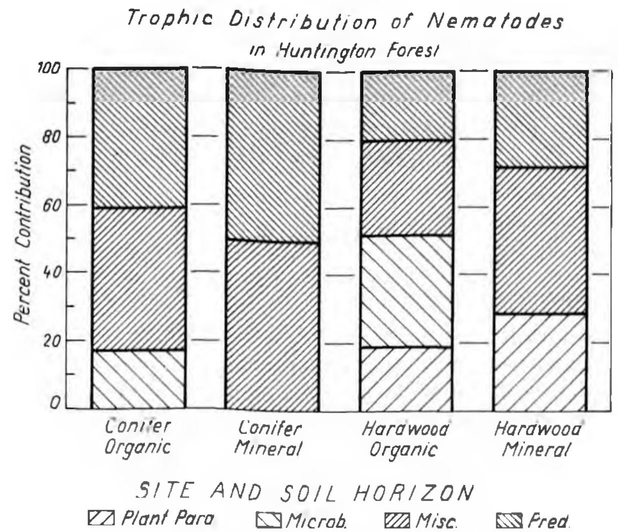

Fig. 1. Percent contribution of major trophic types (Plant Parasites, Microbivores, Miscellaneous Feeders and Predators) in organic and surface mineral horizons of hardwood and conifer forest soils at the Huntington Forest (Adirondack Mountains, New York).

Table 1. Nematode density and biomass in various terrestrial habitats

Habitat	Population density $10^6/mm^2$	Biomass mg/m^2	Mean Individual		
			Dry Mass in μg	Dominant trophic groups	References
Tundra	3.90	180	0.05	—	YEATES 1979
Desert	0.42	25	0.06	—	YEATES 1979
Sewage sludge	14.00	—	2.8	Bacterial feeders	MITCHELL et al. 1978
Rice field	0.05—0.31	23.8 ± 4.46	0.24	Plant parasites and microbivores	MISHRA & DASH 1981
Pasture	0.05—0.22	11.48 ± 1.49	0.13	Plant parasites	MISHRA & DASH 1981
Evergreen forest	2.81 ± 620	128 ± 25	0.05	—	YEATES 1979
Deciduous forest	1.73 ± 563	200 ± 115	0.12	—	YEATES 1979
Douglas-fir forest	0.6 August 2.2 April with an annual mean of 1.3	— —	— —	— —	MCBRAYER *et al.* 1977
Hardwood	2.5 (1.1—6.9)	—	—	—	MCBRAYER *et al.* 1977
Hardwood organic horizons	0.261	5.95	0.0228	Microbivores and miscellaneous feeders	Present paper
Conifer organic organic horizons	0.095	2.16	0.0226	Miscellaneous feeders and predators	Present paper

matodes was 0.0228 $\mu g \pm 0.033$ (50). Biomass for the organic horizons for the hardwood and conifer sites were 5.95 and 2.16 mg m^{-2}, respectively.

No HI-reducible S was found in *Anguilla sp.* and thus all the sulfur was carbon-bonded (LANDERS *et al.* 1983). The total S concentration was 79.8 ± 19.3 (18) μmol g^{-1} [mean $\pm$ standard deviation (n)]. For total carbon, hydrogen and nitrogen the concentrations were 61.9 ± 12.8 mmol g^{-1}, 108.2 ± 21.1 mmol g^{-1} and $4122 \pm 916 \mu$mol g^{-1} (7), respectively.

5. Discussion

5.1. Community composition, population density and biomass

The presence of adult plant parasitic nematodes only in September and not in October or November may have been due to seasonal changes in the sites and limited number of samples. The vertical distribution (Fig. 2) of the nematodes corresponded to highest populations being found in that portion of the soil of maximum organic matter and highest microbial activity (FRECKMAN & CASWELL 1985). The presence of microbivores is indicative of the importance of microbial activity in the organic layers of these sites. The greater predominance of microbivores in the hardwood versus the conifer site may have been a function of the more rapid decomposition in the former site. The increased proportion of dorylaimids in the mineral horizons *versus* the organic soil may be a function of the more stable physical environment in the mineral soil. A low proportion of dorylaimids may be indicative of ecosystem disturbance or changing habitat conditions (JOHNSON *et al.* 1973, 1974; MISHRA & DASH 1981; SOHLENIUS & WASILEWSKA 1984; THOMAS 1978).

The population densities and biomass calculated in the present study were somewhat lower than values reported for other forest soils (Table 1). This may be due to the sampling period of the study in late summer and early fall which is a period of low moisture conditions as well as the limited number of sample replicates. It may be expected that samples from spring would exhibit higher population densities and biomass due to higher moisture conditions and greater microbial activity both of which would cause nematode populations to increase (YEATES 1981).

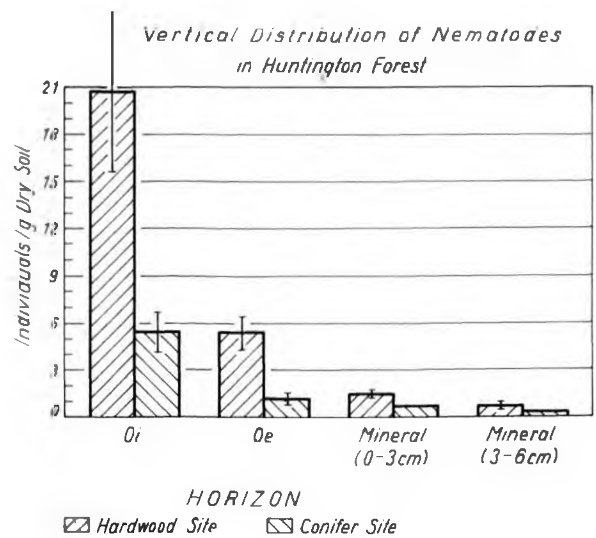

Fig. 2. Densities of nematodes in organic and surface mineral horizons of hardwood and conifer forest soils at the Huntington Forest (Adirondack Mountains, New York); means with standard deviations indicated by vertical lines.

5.2. Contribution of nematodes to soil elemental content

The carbon-bonded sulfur in the nematodes was probably derived from sulfur containing amino acids as such methionine, cysteine and cystine. The elevated N/S ratio of 52 reflects the predominance of nitrogen containing amino acids in these nematodes. The C/N ratio for *Anguilla sp.* of 15 was greater than the mean value of 10 assumed by WOODS *et al.* (1982) and ANDERSON *et al.* (1983a, b). The sulfur and nitrogen contents of the organic layer of the hardwood site were 4.2 g S m^{-2} and 14.8 g N m^{-2}, respectively. Multiplying the mean sulfur and nitrogen concentration of *Anguilla sp.* by the nematode biomass of the nematodes in the organic layer of hardwood site gives values of 15.2 μg S m^{-2} and 343 μg N m^{-2}. This compares to a microbial sulfur content of 1149 μg S g^{-1} of soil for the Oe horizon of Hardwood which constitutes 2.2% of the total sulfur (STRICK & NAKAS 1984). In contrast soil nematodes would contribute only 0.0004 and 0.002% of the total sulfur and nitrogen, respectively. These would be minimal estimates since the sampling period may have caused an underestimate of nematode biomass. In addition, these results should not be interpreted as meaning that nematodes play no role in the sulfur and nitrogen dynamics of the site. Previous work with macroinvertebrates has shown that they affected sulfur flux by feeding and burrowing activities which alter the transfer and transformation of sulfur constituents (LAWRENCE & MITCHELL 1985; MORGAN & MITCHELL 1986). It is expected that the major role of nematodes would be in effects associated with microbial feeding since other investigators have shown for a variety of substrates that the presence of microbivores affects the flux of carbon, nitrogen and phosphorus through the microbial community (ABRAMS & MITCHELL 1980; ANDERSON *et al.* 1983a; COLEMAN *et al.* 1983; FRECKMAN 1982).

To further the understanding of the role of nematodes in forest ecosystems including those at the Huntington Forest more extended studies of their community structure and population dynamics will be required. To integrate these findings into nutrient flux studies, information will be required on the role of nematodes in regulating microbial processes associated with mineralization and immobilization of nutrients including sulfur and nitrogen.

6. Acknowledgements

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Addresses of the authors: Dr. C. C. MISHRA, Department of Soil Science University of Alberta, Edmonton, Alberta T6G 2E3, Canada, and Prof. Dr. M. J. MITCHELL, State University of New York, College of Environmental Science and Forestry, Faculty of Environmental and Forest Biology, Syracuse, NY 13210, U.S.A.

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MISHRA, C. C., & M. J. MITCHELL, 1987. Nematode populations in Adirondack forest soils and their potential role in sulfur cycling. Pedobiologia **30**, 277—282.

The nematode community structure and population density was determined for a hardwood and a conifer site in the Adirondack Mountains of New York (U.S.A.). Two plant parasitic genera, *Hemicycliophora* and *Criconema* were found. For the organic horizons nematode population densities and biomass were 2.61×10^5 individuals m^{-2} (5.95 mg m^{-2}) and 0.95×10^5 individuals m^{-2} (2.16 mg m^{-2}), for the hardwood and conifer sites, respectively.

Carbon, hydrogen, nitrogen and sulfur concentrations were 61.9 mmol g^{-1}, 108.2 mmol g^{-1}, 4122 μmol g^{-1} and 79.8 μmol g^{-1} for *Anguilla sp.* obtained from laboratory cultures. If these concentrations are extrapolated to nematode populations in the field, they would contribute 0.0004 and 0.002 % of the total sulfur and nitrogen in the organic horizon of the hardwood forest. The potential role of nematodes in nutrient cycling of these sites is discussed.

Key words: Biomass, nematodes, northern hardwoods, nitrogen, sulfur, trophic groups.